6. Standard for Traction Electrification Distribution System Inspection, Maintenance and Testing

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Abstract: This standard provides minimum requirements for inspecting, maintaining, and testing rail transit system traction electrification distribution systems and subsystems.

Keywords: distribution, inspection, maintenance, rail transit system, substation, traction electrification, training, qualifications

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Introduction

(This introduction is not a part of APTA RT-FS-S-006-03, *Standard for Traction Electrification Distribution System Inspection, Maintenance and Testing*.)

APTA rail transit safety standards represent an industry consensus on safety practices for rail transit systems to help achieve a high level of safety for passengers, employees, and the general public. This document was created by and for those parties concerned with its provisions; namely, rail transit systems (operating agencies), manufacturers, consultants, engineers, and general interest groups. This standard provides procedures for inspecting, maintaining, and testing rail transit traction electrification distribution systems.

APTA recommends this standard for:

- Individuals or organizations that inspect, maintain, and/or operate rail transit systems
- Individuals or organizations that contract with others for the inspection, maintenance, and/or operation of rail transit systems
- Individuals or organizations that influence how rail transit systems are inspected, maintained, and/or operated (including but not limited to consultants, designers, and contractors)

This standard intends to meet the following objectives:

- To ensure special life/safety equipment is operational and reliable
- To help rail transit systems incorporate safety considerations during the inspection and maintenance process
- To identify inspection criteria and maintenance standards that provide a high level of passenger and personnel safety

The application of any standards, practices, or guidelines contained herein is voluntary. In some cases, federal and/or state regulations govern portions of how an RTS operates. In such cases, the government regulations override any conflicting practices this document requires or recommends.

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Standard for Traction Electrification Distribution System Inspection, Maintenance and Testing

1. Overview

This document establishes a standard for the periodic inspection, maintenance and testing of alternating current (AC) and direct current (DC) traction electrification distribution systems. This includes periodic visual, electrical, and mechanical inspections of components that affect safe and reliable operation. This standard also identifies the necessary qualifications for rail transit system (RTS) employees or contractors that perform periodic inspection, maintenance, and testing tasks.

1.1 Purpose

The purpose of this standard is to verify that traction electrification distribution systems are operating safely and as designed through periodic inspection, maintenance, and testing, thereby increasing reliability and reducing the risk of hazards and failures.

1.2 Scope

This standard applies to rail transit systems that operate electrified light rail and/or heavy rail systems and applies to normal operating conditions. This standard does not apply to commuter railroads that operate on the general railroad system regulated by the Federal Railroad Administration (FRA).

1.3 Alternate practices

Individual rail transit systems may modify the practices in this standard to accommodate their specific equipment and mode of operation. APTA recognizes that some rail transit systems may have unique operating environments that make strict compliance with every provision of this standard impossible. As a result, certain rail transit systems may need to implement the standards and practices herein in ways that are more or less restrictive than this document prescribes. An individual RTS may develop alternates to the APTA standards so long as the alternates are based on a safe operating history and are described and documented in the system's safety program plan (or another document that is referenced in the system safety program plan).

Documentation of alternate practices shall:

a) Identify the specific APTA rail transit safety standard requirements that cannot be met

b) State why each of these requirements cannot be met

c) Describe the alternate methods used

d) Describe and substantiate how the alternate methods do not compromise safety and provide a level of safety equivalent to the practices in the APTA safety standard (operating histories or hazard analysis findings may be used to substantiate this claim).

2. Definitions and acronyms

For the purposes of this standard, the following definitions and acronyms apply:

2.1 Definitions

2.1.1 aerial inspection: An inspection done on an overhead electrical distribution system where the inspector is at the same level as the overhead equipment being inspected.

2.1.2 auto-tension system: A system tensioned by weight or spring to maintain an overhead contact system wire height and a constant wire tension within a defined temperature range.

2.1.3 contractor: Any individual(s) or entity under contract with the rail transit system (including RTS and subcontractor personnel) to install, inspect, maintain, and/or test RTS vehicles, systems, and components. *Syn:* **consultant.**

2.1.4 fixed termination system: An overhead contact system with a contact wire tension that is fixed at a specific temperature and varies for all other temperatures.

2.1.5 heavy rail system: An electric railway capable of a "heavy volume" of traffic characterized by exclusive rights-of-way, multi-car trains, high speed and rapid acceleration, sophisticated signaling, and high platform passenger loading. *Syn:* **elevated railway, rapid rail, rapid transit, subway.**

2.1.6 light rail system: An electric railway with a lighter volume of train traffic than heavy rail that may use shared or exclusive rights-of-way and may run trains intermingled with street traffic. Light rail systems frequently operate with low platform loading and single car trains. *Syn:* **street car, tram, trolley car.**

2.1.7 original equipment manufacturer (OEM): The enterprise that initially designs and builds a piece of equipment.

2.1.8 personal protective equipment (PPE): All clothing and other work accessories designed to create a barrier against workplace hazards. Examples include safety goggles, blast shields, hard hats, hearing protectors, gloves, respirators, aprons, and work boots.

2.1.9 rail transit: All forms of non-highway ground transportation that operate on rail including light rail, streetcars, trolley, and rapid rail transit systems.

2.1.10 rail transit system (RTS): The organization or portion of an organization that operates rail transit service and related activities. *Syn:* **operating agency, operating authority, transit agency, transit authority, transit system.**

2.2 Acronyms

AAS Associate in Applied Science
AC alternating current
APTA American Public Transportation Association
DC direct current
FRA Federal Railroad Administration
OCS overhead contact system
OEM original equipment manufacturer
PPE personal protective equipment
PM preventive maintenance
RTS rail transit system

3. Frequency of tasks

The inspection, maintenance, and testing procedures in this standard shall be performed as specified in Table 1 below as otherwise deemed necessary by the RTS. Since age, type, operating conditions, and environment vary from system to system and OEM maintenance intervals may vary based on operating conditions, the RTS makes the final determination of inspection, maintenance, and testing frequencies based on experience.

Following OEM-specified maintenance intervals for the equipment is recommended. Inspection frequency should be increased for severe operating conditions.

Table 1 - Inspection and maintenance frequencies

Task	Recommended frequency (minimum)	Section
Cable visual and mechanical inspection	Once every 5 years	8.2.1.1 & 8.2.2.1
Cable electrical tests	Once every 5 years	8.2.1.2 & 8.2.2.2
Contact rail visual and mechanical inspection	As determined by the RTS	8.2.3
Overhead contact system walking inspection	Bi-annually (once every 6 months)	8.2.4.1
Overhead contact system aerial inspection	Annually	8.2.4.2
Bond inspection	As determined by the RTS	8.2.5

The RTS shall determine the need for additional inspection, maintenance, and testing frequencies for traction electrification distribution systems. A review of the following factors may be useful in making this assessment:

– OEM-recommended testing intervals

– Industry experience

- Operating environment/conditions
- Historical data
- Reliability-centered maintenance program development
- Failure analysis
- RTS testing and experience
- Regulatory requirements

The frequency of tasks shall comply with applicable federal, state, and local regulations.

4. Qualifications of maintenance personnel

Due to the nature and hazards associated with electrical work on high voltage AC and DC components, maintenance personnel must meet minimum recommended qualifications to perform many inspection, maintenance and testing tasks. Each system shall determine what their needs and resources are. For example, systems may wish to consider a combination of written and practical experience together with continuing education programs geared toward traction and electrification systems maintenance.

4.1 Skills and knowledge

Each RTS shall ensure that the employees and/or contractors that perform periodic inspection, maintenance, and testing have the knowledge and skills necessary to safely and effectively perform the tasks assigned to them.

4.1.1 Basic inspection level

Inspectors must have a minimum of two years experience working with electrical systems. All inspectors must be familiar with the installation and repair of the components associated with the electrical systems.

4.1.2 Maintenance level

Maintainers must have three or more years experience working on high voltage power distribution or related traction and electrification systems either by in-house experience or recognized trade school or apprenticeship training program.

4.1.3 Technician level

Technicians must have three or more years experience working on high voltage power distribution or related traction and electrification systems or possess an Associate in Applied Science (AAS) degree in electrical systems or equivalent.

4.2 Continuing education

A RTS should establish a continuing education program for the above positions based upon its specific operation and requirements.

5. Tools

The following tools are required for inspection, maintenance, and testing of traction electrification distribution systems:

- Torque wrench
- Multi-meter*
- Megohm-meter*
- Gage measuring device
- Standard tools carried by electrical maintenance workers

* Calibrate in accordance with OEM and/or RTS requirements.

6. Safety

RTS safety rules, procedures, and practices shall be followed at all times during inspection, maintenance, and testing.

7. Personal protective equipment

Personal protective equipment, as required by the RTS, shall be worn at all times during inspection and testing.

8. Inspection, maintenance, and testing

Rail transit systems shall evaluate their local operating environment and conditions to develop suitable inspection, maintenance, and testing programs.

8.1 Inspection, maintenance, and testing categories

a) *Periodic inspection and maintenance* shall be performed to verify proper system operation and general system upkeep.

b) *Preventative maintenance (PM) and testing* may require removing the equipment from service and performing tests on the equipment or the materials to ensure proper operation. This type of maintenance occurs on a regularly scheduled basis.

8.2 Policies and procedures

Each RTS shall develop specific written policies and procedures that take into account specific equipment designs and local operating conditions to implement the inspection, maintenance, and testing required by this standard. These policies and procedures shall give maintenance staff clear guidance and criteria for performing these activities.

8.2.1 Cables – 600V to 1500V DC

8.2.1.1 Visual and mechanical inspections

The RTS shall perform the following inspections on all positive and negative cables when cable failure occurs in areas such as, conduit, duct bank, or trough.

Annex A contains a sample inspection form for recording the results of cable inspections and tests.

a) Inspect exposed sections of cables for physical damage or evidence of overheating.

b) Inspect fireproofing in common cable area and firewall penetrations, if present.

c) Inspect terminations, jumpers, and splices for evidence of physical damage or overheating.

d) Inspect bolted electrical connections for high resistance using one of the following methods:

   – Use calibrated torque-wrench method in accordance with OEM published data to verify tightness of accessible bolted electrical connections.

   – Perform a thermographic survey of the equipment under loaded conditions.

e) Inspect the cable support and termination.

8.2.1.2 Electrical tests

a) Perform resistance measurements on bolted connections with a low-resistance ohmmeter capable of reading 2 microhms or with parallel cables use a clamp-on ammeter to verify nearly equal currents on all cables.

b) Perform an insulation-resistance test only when the integrity of a cable is suspect with a megohmmeter using a voltage no greater than the cable insulation rating. Where there is more than one cable in parallel, test each individual cable.

8.2.1.3 Test values

a) Compare bolted connection resistances to values of similar connections.

b) Ensure bolt-torque levels are in accordance with OEM recommendations.

c) Ensure microhm or millivolt drop values do not exceed the high levels of the normal range as indicated in the OEM published data. If OEM data is not available, investigate any values that deviate from similar connections by more than 25 percent of the average value.

d) Compare test results to previously obtained results.

8.2.2 Cables – 600V AC and above

8.2.2.1 Visual and mechanical inspections

The RTS shall perform the following inspections on line neutral and ground cables when cable failure occurs in areas such as, conduit, duct bank, or trough.

a) Inspect exposed sections of cables for physical damage, evidence of overheating or corona.

b) Inspect fireproofing in common cable area and firewall penetrations, if present.

c) Inspect terminations and splices for evidence of physical damage, overheating or corona.

d) Inspect all bolted electrical connections for high resistance using one of the following methods:

   – Use calibrated torque-wrench method in accordance with OEM published data to verify tightness of accessible bolted electrical connections.

   – Perform a thermographic survey of the equipment under loaded conditions.

e) Inspect the shield ground (if present), cable support and termination.

8.2.2.2 Electrical tests

a) Perform resistance measurements on bolted connections with a low-resistance ohmmeter capable of reading 2 microhms.

b) Perform an insulation-resistance test only when the integrity of a cable is suspect with a megohmmeter using a voltage no greater than the cable rating. Where there is more than one conductor cable in parallel, test each individual conductor.

8.2.2.3 Test values

a) Compare bolted connection resistances to values of similar connections.

b) Ensure bolt-torque levels are in accordance with OEM recommendations.

c) Ensure microhm or millivolt drop values do not exceed the high levels of the normal range as indicated in the OEM published data. If OEM data is not available, investigate any values that deviate from similar connections by more than 25 percent of the average value.

d) Compare test results to previously obtained results.

8.2.3 Contact rail

The RTS shall develop specific inspection criteria for contact rails based on the type of contact rail in service and system requirements. The RTS shall inspect the components listed in Sections 8.2.3.1-8.2.3.8 as a minimum during each inspection interval.

Annex A provides an example of an inspection form that can be used to record the results of contact rail inspections and tests.

8.2.3.1 Contact rail integrity

a) Verify the contact rail has proper horizontal and vertical relation to the adjoining running rail.

b) Inspect the contact rail for wear. Measure the wear on the head/ball of the rail. Compare the amount of contact rail material remaining to the original profile of the head/ball of the rail using some form of gage measuring device. Replace rail in accordance with RTS requirements.

8.2.3.2 Expansion joints/gaps

Expansion joints/gaps are installed at various locations to allow for the thermal expansion and contraction of the contact rail.

Check for proper alignment and signs of movement.

8.2.3.3 Power section gaps

Section gaps provide a means of power isolation. Section gaps are designed to a specific minimum length to prevent energization of adjacent sections through the current collectors of a single rapid transit car.

Check the length of the section gap.

8.2.3.4 Inclines

Inspect inclines (also called approaches) for wear, height, gage, and proper support.

Compare measurements taken to design standards.

8.2.3.5 Contact rail anchors

Inspect contact rail anchors for integrity.

8.2.3.6 Contact rail insulator

Inspect all contact rail insulators for cracked, loose and/or missing contact rail insulators, particularly in curves and at inclines.

8.2.3.7 Contact rail bonds

Inspect the physical condition of all contact rail bonds including welds and mechanical connections.

8.2.3.8 Knife switches

Check the condition of the knife switch for arc burns, insulator integrity and freedom of movement, operating mechanism and connecting cables.

8.2.4 Overhead contact system (OCS)

Although all overhead contact systems consist of similar types of equipment, each type varies greatly depending on age, type, and manufacturer. This standard cannot cover each type of installation, however Section 8.2.4.1-8.2.4.2 contain procedures common to all types of overhead contact systems.

8.2.4.1 Walking Inspection

a) Check foundations for visible cracks, spalling, base details and fasteners, deposits of trash, over growth of vegetation, and concrete condition.

b) Check poles (particularly termination poles) for loose nuts of bonding cables, broken or cracked welds, damaged galvanization, distortion, cracking, or corrosion.

c) Check the integrity of bonding cables.

d) Check the completeness, cleanliness, and proper attachment of warning signs and pole number signs.

e) Check insulators and cable terminations for damage or dirt.

f) Check position of insulators, steady arms, and contact wire clips.

g) Check for broken wires at contact wire supports.

h) Check catenary for broken or displaced hangers,

i) Check the position of contact wire bridges at crossovers and the position of wires at overlaps and crossovers.

j) Check frogs and switches, cantilever assemblies, and for slackened or missing jumpers.

k) Check the balance weight or tension spring assembly for corrosion of steel wire.

l) Check the free movement of the pulley wheel.

m) Check the position of the weight stack depending on the temperature and alignment of the wires on the pulley.

n) Check the condition of the disconnect switch for arc burns, insulator integrity, freedom of movement, and connecting cables.

o) Check section insulator running skids for wear and correct adjustment. Wash off carbon deposits with a mild detergent.

p) Check tension spring assembly (where used) for corrosion of steel wire and free movement of the pulley wheel

q) Check the length of the spring depending on the temperature and alignment of the wires on the pulley.

8.2.4.2 Aerial inspection

Perform the following as required during the high rail inspection:

a) Check the stagger of the contact wire at supports and at mid-span and adjust as necessary.

b) Check the steady arm inclination and adjust as necessary.

c) Check the adjustment of the outrunning wires in overlap sections and at crossovers.

d) Check the contact wire for twists, kinks and spots of arcing. If the cross sectional area is more than 30% worn, replace the contact wire.

e) Check the messenger wires, head-span wires, dropper wires, ground wires and feeder wires for corrosion, damage, broken strands, and evidence of arcing. Wires should be carefully monitored for arcing due to hard spots, particularly near clamps. Make adjustments as necessary.

f) Check the contact blades for dirt and arcing damage. Connecting wires and clamps should be free of cracks and arcing damage.

g) Check all movable parts of the switch assembly, operating link, contact blades, and operating handle for free movement and adjust if necessary.

h) Re-lubricated all movable parts of the switch assembly, operating link, contact blades, and operating handle as required.

i) Check the correct position of the section insulators and the even wear of the runners.

j) Check the contact wire termination for cracks and excessive wear, and for damaged suspension assembly. Adjust as necessary.

k) Check the catenary for:

- Contact wire height above top of rail.

- Contact wire stagger from centerline of track at supports and in center of span.

- Sag of the wire in relation to the temperature if a fixed terminated system is employed.
- The position and condition of hangers, cantilevers, steady arms, clips, and other attachments.
- Cantilever lateral movement according to design, if auto tension system is employed.
- Proper clearance envelope.

8.2.5 Bonds

8.2.5.1 Running rail bonds

Running rail bonds are installed across the running rail joint to supplement the electrical connection for negative traction return currents and can affect signal system reliability.

Inspect the welds and mechanical connections for cracks and corrosion and fraying of the bond.

8.2.5.2 Structure bonds

Elevated structures are sometimes used to supplement the negative traction return current. Structure bonds are typically connected from the running rail to the structure and across a mechanical connection between structural elements.

Inspect the welds and mechanical connections for cracks and corrosion and fraying of the bond.

8.2.5.3 Cross bonds

Cross bonds are installed to supplement the electrical connection for enhanced negative return and reduction of stray current.

Inspect the welds and mechanical connections for cracks and corrosion and fraying of the bond.

8.2.5.4 Impedance bonds

Impedance bonds are installed to maintain the continuity of the traction return currents in signalized territory.

Inspect the welds and mechanical connections (particularly the rail end weld/pin/clamp connection) for cracks, corrosion, and bond fraying.

8.2.5.5 Contact rail and running rail connections

Contact rail and running rail connections provide the electrical connection between the traction power distribution positive and negative cables and their respective rails. Contact rail and running rail connections are typically welded to the base of the rail or mechanically fastened to the rail.

a) Inspect the welds and mechanical connections for cracks and corrosion and fraying of the bond.

b) Inspect all mechanical support systems on elevated tracks.

9. Correction of deficiencies

Deficiencies identified during inspection, maintenance, and testing shall be corrected and documented in accordance with OEM and/or RTS requirements. Some operational equipment may need to be taken out of service immediately until the problem is corrected. Other equipment may be left in service and corrected when parts, tools and /or appropriately skilled manpower are available.

The RTS shall designate a person responsible for deciding whether or not to leave defective equipment in service in order to operate. In the absence of a designated person, the RTS shall take the equipment out of service.

The RTS shall review and develop a corrective action plans for documented system defects monthly.

10. Priority ratings

The RTS shall develop a priority rating system to evaluate and determine the effects that any single defect will have on the system if they choose to operate with a known defect.

Recommended priority ratings are:

- Priority 1: The defect will endanger the safety of patrons and personnel and/or continuation of revenue service. A permanent or temporary repair shall be made immediately.

- Priority 2: The defect may cause disruption of revenue service. The repair shall be made in a predetermined timeframe set by each system.

- Priority 3: The defect will not affect revenue service. The repair shall be made in a predetermined timeframe set by each system.

11. Documentation

The RTS shall develop and implement a fully auditable process for recording and tracking inspection, maintenance, and testing activities and outstanding system defects. Such documentation shall be documented, reviewed, and filed in accordance with RTS procedures and OEM recommendations. Documentation should be kept for the life of all in-service equipment and be readily available for review.

Annex A contains a sample checklist and recording form that rail transit systems can adapt to their specific equipment and operating environment.

Annex A

(Informative)

Sample checklist/recording form

CONTACT RAIL MAINTENANCE RECORD — Trouble and Inspection Sheet

Start Location ______________ End Location ______________ Foreman ______________

Job No.	Line	Location	Station Number	Track Number	Priority Number		Time & Date Reported	Time & Date Given	By	Contact Rail Defect/Repair Code	Remarks	Time & Date Started	Time & Date Repaired	By
						Defect								
						Repair								
						Defect								
						Repair								
						Defect								
						Repair								
						Defect								
						Repair								
						Defect								
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						Repair								
						Defect								
						Repair								
						Defect								
						Repair								
						Defect								
						Repair								

Priority: 1 — Immediate, 2 — Essential, 3 — Secondary, 4 — Non-essential

FOR CODES REFER TO: DEFECT/REPAIR CODE SHEET ON OTHER SIDE

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(front)

Date	Additional Remarks	By

700 DEFECT — REPAIR CODES

Anchors — ANCR

AD — Anchor Defective
ABM — Anchor Bolt Missing
ABL — Anchor Bolt Loose
AW — Anchor (Wood to be replaced)
ANC — Anchor

Chairs — CHRS

CCB — Chair Clip Bad
CM — Chair Missing
CL — Chair Leaning
CB — Chair Broken
CTD — Chair Tie Defective
CLM — Chair Lag Screw Missing
CHR — Chair

Contact Rail — CRAIL

CRC — Contact Rail Cracked
CRF — Contact Rail Floating
CRL — Contact Rail Low
CRH — Contact Rail High
CRW — Contact Rail Worn
CRG — Contact Rail Out of Gauge
CRD — Contact Rail Dished
CRM — Contact Rail Moved
CRA — Contact Rail

Contact Rail Joints — CRJT

JPD — Joint Plates Defective
JBL — Joint Bolts Loose
JBM — Joint Bolts Missing
JHL — Joint Huck Bolts Loose
JHM — Joint Huck Bolts Missing
JH — Joint Hot
JRM — Joint Rail Mismatched

Contact Rails (Tap) — CRTP

TBM — Tap Brass Bolt Missing
TBL — Tap Brass Bolt Loose
TBC — Tap Clamp Broken
TCC — Tap Clamp Cracked
TLH — Tap Lug Hot
TLC — Tap Clamp Bolt Loose
TLD — Tap Legs Defective
TM — Tap Moved
TAP — Tap

Contact Rail Bonds (Positive) — CRBD

BPM — Contact Rail Bond Defective or Missing
BPB — Contact Rail Bond Broken
BPH — Contact Rail Bond Hot
PPH — Positive Pothead Defective or Missing

Inclines — INCL

IC — Incline Cracked
IL — Incline Loose
IW — Incline Worn
IH — Incline High
IOG — Incline Out of Gauge
ICM — Incline Chair Missing
ILH — Incline Length
ID — Incline Dished
INC — Incline

Negative Rail Bonds (Power) — NRBD

BND — Negative Bond Defective or Missing
BNS — Negative Structure Bond Defective of Missing
BNP — Negative Pothead Bond Defective or Missing
BPH — Negative Pothead Defective or Missing
BON — Negative Bond

Negative Rail Bonds (Signal) — SIGBD

SBD — Signal Bond Defective or Missing
SWD — Signal Wee Zee Bond Defective or Missing
SBN — Signal Bond

Rail Gaps — RGAPS

GSC — Gap Section Closed
GEC — Gap Expansion Closed
GAP — Gap

Other Defect — OD

OD — Other Defects

Repair Codes — REPCD

REP — Repaired
RPL — Replaced
REV — Re-evaluated
OOS — Out of Service
CLN — Cleaned
PNT — Painted
REL — Relocate
INS — Install New

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